**COMET BAY COLLEGE**

**Physics Unit 3 - Task 6**

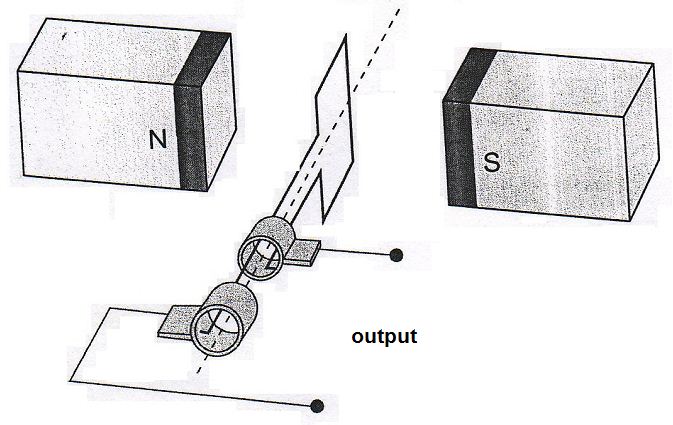
**Electromagnetism Test 2**

**Name: SOLUTION Total Marks /56**

**Question 1**

The diagram below shows an AC generator consisting of a rectangular coil with dimensions of

14.0 cm × 21.0 cm, and 800 turns of copper wire. The magnetic flux density between the poles is 9.40 mT. The coil is turned at a uniform rate.



**SR**

**B**

**B**

1. Referring to Lenz’s law, explain how induced emf is achieved from such a generator and why the output is a sine or cosine shape rather than being constant. (3 marks)

**As the coil rotates the amount of flux contained within the coil changes. Lenz’s Law states that the emf is generated in the coil that induces current to flow ✓ in a direction such that its own field will oppose the change in the magnetic field that caused it to be generated✓**

**The emf is proportional to the rate of change of flux (amount of field lines being cut). The rate of change is zero when maximum flux is contained and maximum when the flux is zero. This leads to the sine shape of output voltage. ✓Or similar.**

1. The coil is rotated at 1500 rpm. Calculate the magnitude of the average induced emf in the coil as it rotates through 90º from the position shown. (3 marks)

**N = 800 1500 rpm 🡪 f= 1500 / 60 = 25.0 Hz**

**Time for 1 revolution = Period = 1/f = 1/25 = 0.04 s**

**Time for ¼ revolution = 0.01 s**

**Φ1 = B.A = 9.40 🞩 10-3🞩 0.14 🞩 0.21 = 2.7636 🞩 10-4**

**Φ2 = 0 ✓**

**emf = -N(Φ2 - Φ1) / t = -800 🞩 (0 - 2.7636 🞩 10-4) / 0.01 ✓**

**emf = 22.1 V ✓**

1. Sketch the emf output curve for this AC generator on the graph below. You must start from the position shown on the diagram and continue up to 80 ms. Make estimates for values that you cannot calculate. (3 marks)

**Initial emf = zero ✓**

**period = 40 ms ✓**

**max emf shown larger than average. ✓**

**(NB peak emf = VRMS 🞩 √2**

**¼ turn method has approx -10% error compared to RMS**

**‘750 rpm curve’**



1. Indicate three times on the graph when the flux enclosed by the coil is a maximum value at 1500 rpm. **Circle** these times. (1 mark)

**Times are 0 20 40 60 or 80 ms when the emf = zero. Any 3 ✓**

1. When the coil is rotated at 750 rpm the emf output changes. Sketch a second voltage curve onto the graph and clearly label it ‘750 rpm curve’. (1 mark)

**Shows Period = 80 ms and emf max is ½ of 1500 rpm curve✓**

**Question 2**

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Rail falling at 25.0 m/s within magnetic field

An iron rail of mass 150 kg and length 4.22 m is falling at 25.0 m s-1 next to a magnetic pole of a large electro-magnet in a breakers yard. The magnetic flux density of the electro-magnet is 840 mT and its direction is indicated in the diagram.

1. Calculate the potential difference across the length of the rail. (2 marks)

**l = 4.22 m v = 25.0 m/s B = 0.840 T**

**emf = lvB = 4.22 x 25.0 x 0.840 (1 mark)**

**emf = 88.6 V (1 mark)**

1. Explain, referring to charge location, how a potential difference is established in this situation. (2 marks)

**Electrons are forced to the left hand side of the rail. (1 mark)**

**This establishes a region of negative charge at the left and a region of positive charge at the right. (1 mark)**

**Question 3**

The figure below represents a DC motor whose coil is initially stationary.

* JK = LM = 16.0 cm KL = JM = 12.0 cm
* The coil has 120 turns of wire
* The uniform magnetic flux density between the poles = 95.0 mT
* The current in the coil is 6.30 A when the motor is switched on and it turns clockwise.



a) In which direction, clockwise or anticlockwise will the motor rotate when the switch is closed? (1 mark)

**The coil of the motor will rotate in an anticlockwise direction.**

b) Explain your answer to part (a). (2 marks)

**Using the right hand rule, the force on the side JK is downwards and the force on side LM is upwards. This will rotate the coil in the anticlockwise direction about the axis. The forces on the wire are due to the interaction of the field around the coil and the field of the permanent magnet.**

1. Indicate the positive and negative terminals on the DC power supply for this direction of rotation. (1 mark)

**Negative left, positive right ✓**

1. Calculate the force acting on side LM of the coil when the switch is closed. (2 marks)

**F = B.I.l.N**

**F = 0.095 🞩 6.30 🞩 0.16 🞩 120✓**

**F = 11.5 N down ✓**

1. Calculate the maximum torque that this motor can produce. (2 marks)

**τmax = 2 🞩 r.F.sin θ θ = 90°**

**τmax = 2 🞩 0.06🞩 11.5 🞩 sin 90°✓**

**τmax = 1.38 N m clockwise ✓**

**Question 4**

A teacher set up a model to demonstrate how electricity is distributed using a power supply, transmission wires, meters and a transformer. A diagram of the model is shown below. Resistance in the wires connecting the **power supply, transformer and globe** to the transmission lines can be ignored.



The transformer is ideal (100% efficient) and the ratio of primary to secondary windings is 5:1.

* 1. If the current through ammeter A1 is 0.5 A, calculate the following:

1. The reading on ammeter A2 (2 marks)

**Power delivered on each side of the transformer is equal. Voltages are in the ratio of 5 : 1 and transformer is ideal (no energy losses)**

**P = V I**

**Vp Ip = Vs Is**

**5 x 0.5 = 1 x A2**

**A2 = 2.5 A**

1. The reading on voltmeter V1 (2 marks)

**R = 4 Ω**

**I = 2.5 A**

**V = I x R**

**V = 2.5 x 4 = 10 V**

**Reading on meter V1 is 10 V**

1. The reading on voltmeter V2 (2 marks)

**Ratio of turns on primary : secondary :: 5 : 1**

**current in primary coil = 0.5 A**

**voltage in primary coil = 10 V ac**

**Transformer equation Vs / Vp = Ns / Np**

**Vs / 10 = 1 / 5**

**Vs = 2.0 V = the reading on voltmeter V2**

b) If the AC power supply is replaced by a 12V battery, what will be observed at the globe? (1 mark)

**There will be NO power delivered to the globe.**

c) Explain your answer to (4c) in terms of the operation of the transformer. (2 marks)

**The battery is DC. For a transformer to work there needs to be a continual change of the magnetic flux. An AC supply provides a fluctuating current which is changing the flux as it alternates between maximum and minimum.**

1. In the real world electric power is distributed over large distances at high voltages. Explain why. (2 marks)

**Large currents are responsible for large energy losses in transmission lines so electric power is distributed at high voltages and lower currents to minimize losses. 12 V potential difference would be insufficient to power domestic and industrial appliances. Also if the voltage was DC it could not be used to step up and step down voltages in transformers.**

**Question 5**

A light globe that is plugged into the mains electricity supply of an Australian house is actually switching on and off 100 times per second. This is because the mains electricity is powered by Alternating Current (AC). If current is plotted against time it is a sinusoidal wave form with a frequency of 50 Hz. The light globe will glow at its brightest when current has a maximum magnitude and will momentarily be switched off as the current changes direction.

**Emf maximum = 340 V**



*Graph 1 showing alternating emf in an Australian household mains supply*

Diagram 1 shows the coil PQRS of an AC generator placed between magnetic poles.

* A uniform magnetic field of flux density 0.126 T exists between the magnetic poles.
* The dimensions of the coil are: PQ = SR = 17.0 cm and PS = QR = 9.00 cm
* The coil rotates about the axle as indicated as a torque is applied to the pulley.
* The coil has 600 turns of wire and is rotated uniformly at 840 rpm.

Diagram 1 – AC generator viewed from the top. Coil PQRS sits flat in the magnetic field between the North and South magnetic poles shown.

Contacts to external circuit

Slip rings

Pulley that turns coil

Axle

**P**

**R**

**Q**

**S**

PQ rotates out of page

SR rotates into page

Current

Current

**S**

**N**

Diagram 2 – The AC generator viewed from the front (location of the slip rings) after coil PQRS has rotated by 20° from the position shown in Diagram 1.

**S**

**N**

Axle

1. Why does the passage state that a light globe switches on and off 100 times per second when the AC frequency is 50 Hz. (2 marks)

**The globe is on regardless of the direction of current 🗸 Within a cycle the current flows one way, stops and then flows the other way 🗸 2 x 50 Hz = 100 times per second.**

1. A simple AC circuit has a resistance of 4.00 Ω and is driven by an RMS voltage of 120 V. Determine the maximum current that will flow through the resistor as part of the AC cycle.

(3 marks)



**so Vmax = 120 x = 169.7 V 🗸**

**so 🗸**

At the instant shown in diagram 2, the magnitude of emf is: (**circle** a response) (1 mark)

Increasing Zero Decreasing Staying Constant

1. Explain your response to the previous question. (2 marks)

**The rate of change of flux is decreasing as the coil approaches maximum flux captured by the coil. 🗸 emf is directly proportional to the rate of change of flux. 🗸**

1. Consider the lengths PQ and RS in the AC generator in Diagram 1. They can each be considered as long straight conductors and the emf generated across them is a maximum when they move in a direction perpendicular to the magnetic field lines. From the starting point of derive the equation showing clear logical steps.

(3 marks)

**for 1 length, and 🗸**

**There are 2 lengths each with N turns so, 🗸**

**The radius r is the distance from the axle to each length so**

**, and by substitution**

**🗸**

1. Calculate the maximum emf (Vmax) for the AC generator shown in Diagrams 1 and 2.

(3 marks)

**N = 600 f = 840/60 = 14 Hz B = 0.126 T A = 0.17 x 0.09 = 0.0153 m2 🗸**

**🗸**

**= 101.7 = 102 V 🗸**

1. Determine the RMS voltage of this AC generator. (2 marks)

**Identifies that= 102 V from the graph🗸**

**🗸**

**Question 6**

The figure below represents an alternator consisting of a rectangular coil with sides of

0.15 m x 0.20 m and 1200 turns, rotating in a magnetic uniform field. The magnetic flux through the coil in the position shown is 2.5 x 10-4 Wb.



a) Calculate the magnitude of the magnetic field strength. (3 marks)

**area of coil (A) = 0.15 x 0.20 = 0.03 m2**

**number of turns (N) = 1200**

**magnetic flux (Φ) = 2.5 x 10-4 Wb**

**Φ = B A**

**2.5 x 10-4 = B x 0.03**

**B = 2.5 x 10-4 / 0.03**

**B = 8.3 x 10-3 T**

1. If the coil rotates half a revolution from its starting position in 0.03 s, calculate the magnitude of the average induced emf in the coil in this time. (3 marks)

**time for ¼ of a revolution = 0.0.015 s**

**(Φ goes from max to 0 during this time)**

**magnetic flux = 2.5 x 10-4 Wb**

**number of turns = 1200**

**emf = -N (Φ - Φ)/t**

**emf = -1200 (2.5 x 10-4 – 0)/0.015**

**emf = 20 V**